Observations on Current and Possible Future Electric Vehicle Markets: with an Emphasis on Truck Transportation

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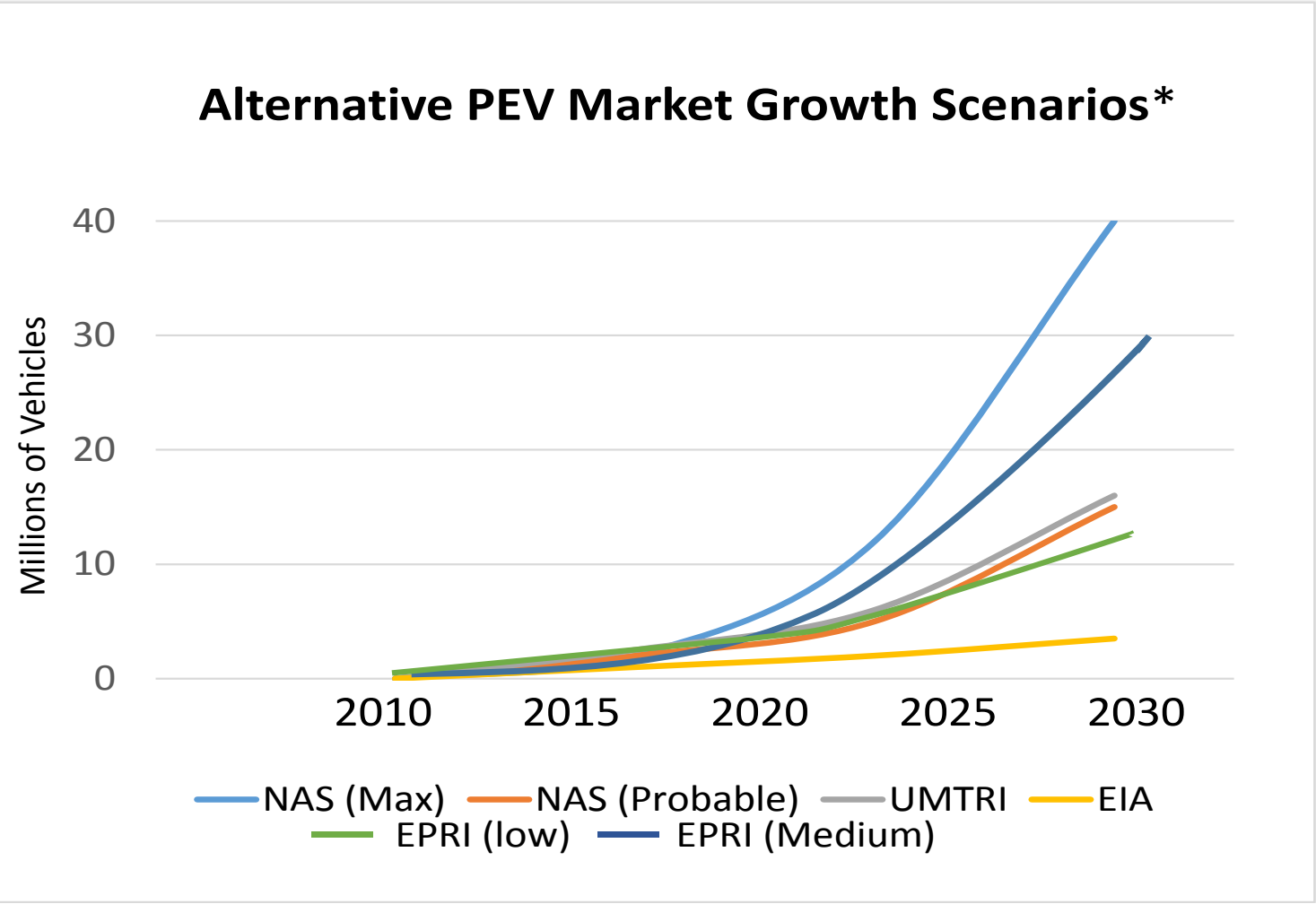
Outline of The Talk

Some Observations On…

A. The U.S. Passenger Car EV Market
   - A1. Recent and Projected Growth
   - A2. S.W.O.T Analysis
   - A3. The U.S. EV Charging Infrastructure

B. The U.S. Truck Freight EV Market
   - B1. Light, Medium and Heavy-Duty Market Niches
   - B2. HEV and AEV for Urban and Long-Haul Trucking
   - B3. EV Supported Multi-Niche Freight Supply chains
   - B4. The Potential of Smart E-Highways

A. Recent and Projected Growth in Light Duty EV Market in the USA



* **Sources:** Scenarios drawn from C. Zhu and N. Nigro (2012) PLUG-IN ELECTRIC VEHICLE DEPLOYMENT IN THE NORTHEAST A Market Overview and Literature Review. CenterforClimateand EnergySolutions(C2ES), and https://www.fhwa.dot.gov/environment/climate_change/mitigation/publications_and_tools/ev_deployment/page03.cfm

EV Adoption: S.W.O.T. Analysis

Strengths:

- Lower per mile operating and maintenance costs
- Positive perception of environmental benefits (less oil use, lower CO2 emissions*, quieter vehicle operation)
- Quicker pickup speeds from standing starts over comparable non-EV models
- Low operating noise makes nightly truck (freight) distribution more acceptable in residential areas
- Use of elec. to power on-site tools or replace diesel idling

Weaknesses:

- Higher Up-Front Purchase Cost
- "Range Anxiety"
- Recharging time (and rapid re-charging station installation cost/inconvenience)
- Currently limited number and location of re-charging stations
- Concerns over battery lifetime, including concern over vehicle resale value
- Concern over buying into EV technology "too soon" (i.e. before more mature, tested and better value options come onto the market)

Opportunities:

- Government/Industry Subsidies (including Tax Breaks, Preferential Leasing and Parking, HOV Lane Use)
- **Future Development of Grid-Powered "Smart" Highways**

Threats:

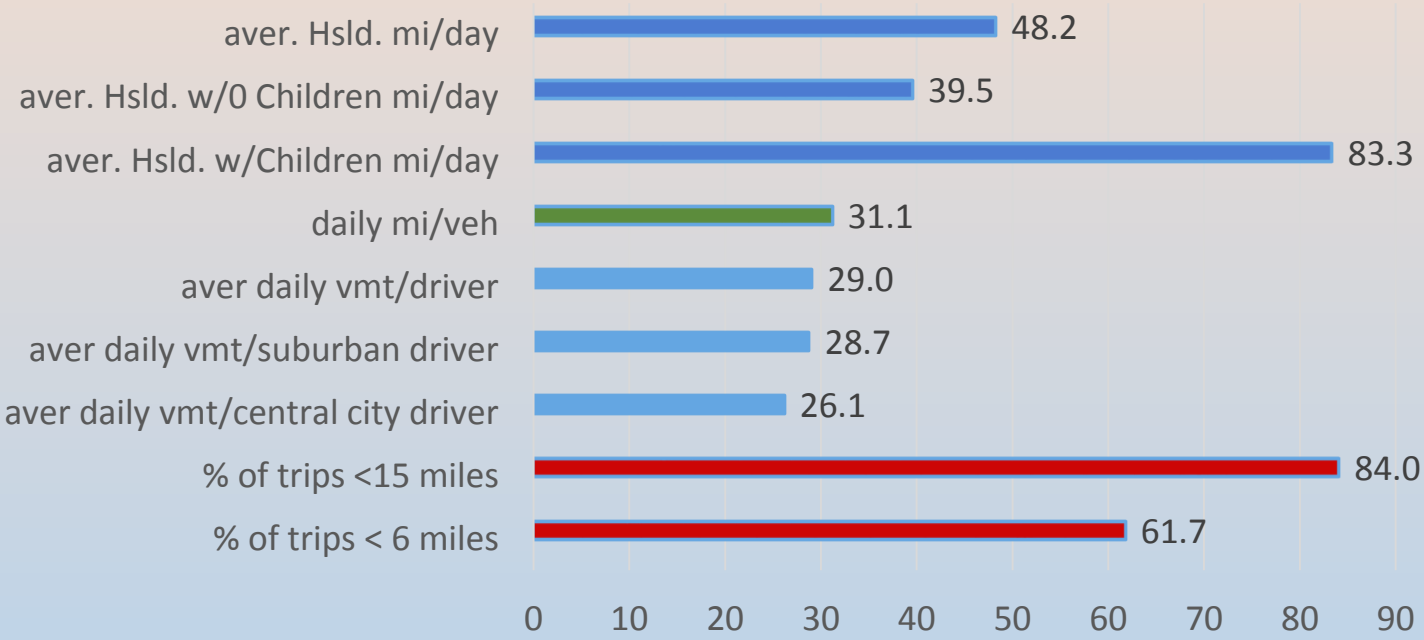
- Low cost of alternative fuel (power) sources
- Slow expansion and cost of charging infrastructure
- Lack of charging equipment standards

* Unless coal-based electricity

EV Driving Range Concerns: Becoming More Perceived Than Real

U.S. Household Driving Statistics

(See TEDB Edn. 34, 2015: based on NHTS, 2009 data)

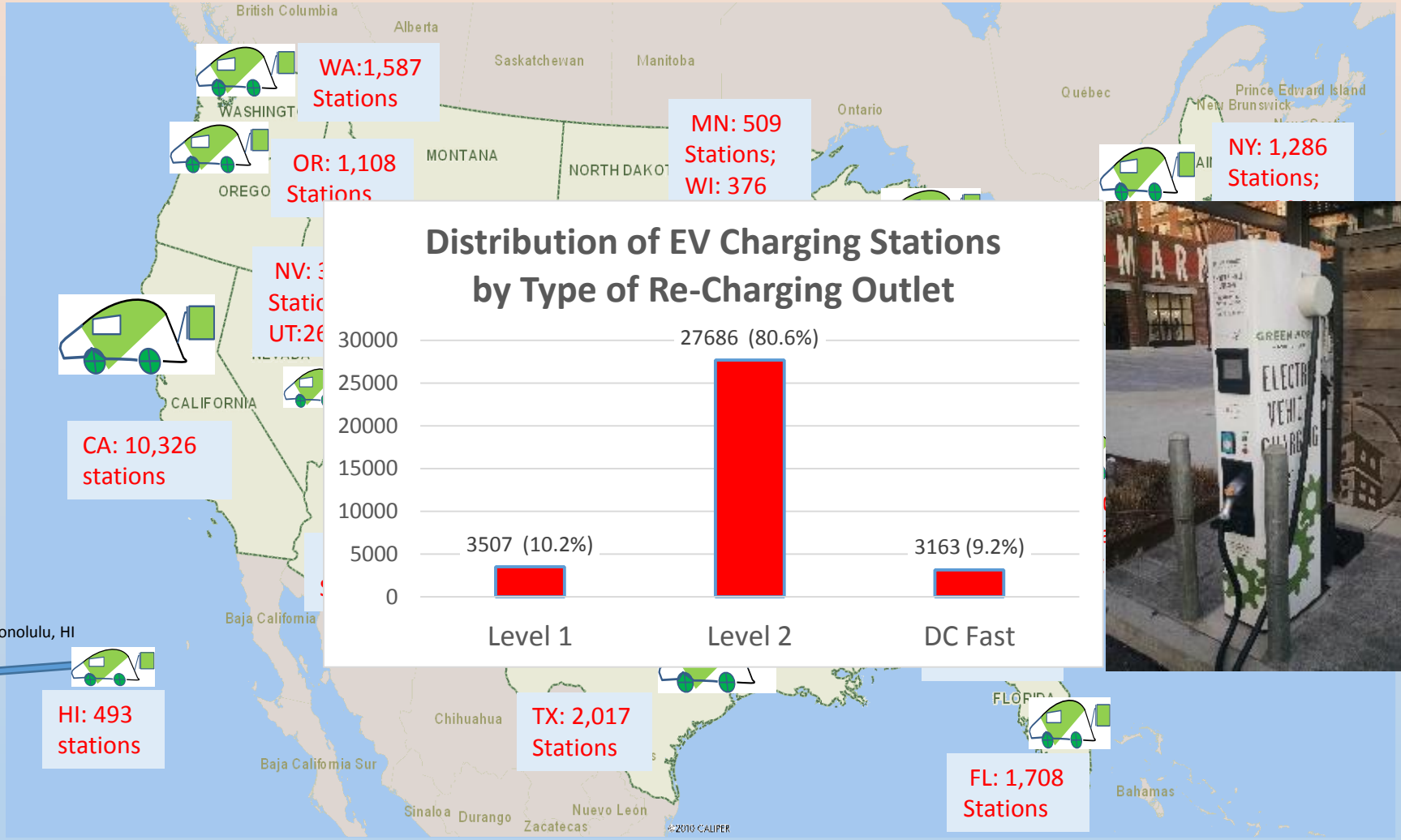


- PEVs such as the Nissan Leaf are capable of more than 80 miles per charge, which **is estimated to satisfy between 80% to 90% of daily household vehicle driving needs**,* and may not be a constraint on trip-making if a household owns a second, e.g. hybrid, vehicle.

- "Range anxiety" currently leads some drivers to maintain a significant "safety margin". **However, this situation ought to change with greater familiarity with/knowledge of EV performance**, especially as AEV technology improves.

* See, for example, M. Khan and K. Kockelman (2012) Predicting the market potential of plug-in electric vehicles using multiday GPS data. *Energy Policy 7/2012.*

States with > 250 EV Charging Locations* in the USA in 2015



> 11,800 electric stations, > **34,300** charging outlets in the United States

http://www.afdc.energy.gov/ http://www.afdc.energy.gov/data/10366

Accessed 5th January, 2016

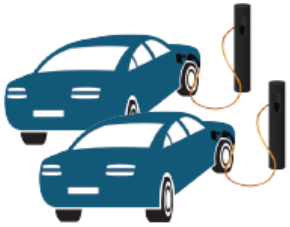
* Public and Private Stations

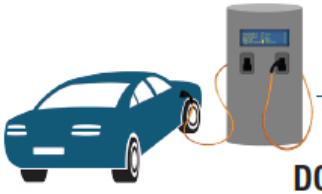
EV Everywhere grand challenge blueprint

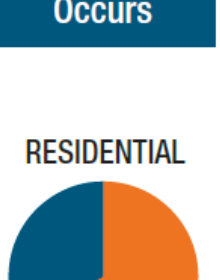
U.S. DEPARTMENT OF ENERGY January 31, 2013

Alternative EV Charging Levels

Charging Level	Setting	Supply Power	Representative Example	Where Charging Occurs
AC Level 1	Residential/ Parking Lot 5 mi/hour @ 1.7 kW	120vac/20A (16A continuous)		RESIDENTIAL
AC Level 2 (minimum)	Residential/ Commercial 10 mi/hour @ 3.4 kW	208/240vac/20A (16A continuous)		2/3 of charging
AC Level 2 (maximum)	Commercial (up to) 60 mi/hour @ 19.2 kW	208/240vac/100A (80A continuous)		
DC Level 1	Commercial up to 500v @ 80Adc (up to) 120 mi/hour @ 40 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-200A AC)		COMMERCIAL
DC Level 2	Commercial up to 500v @ 200Adc (up to) 300 mi/hour @ 100 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-400A AC)		1/3 of charging





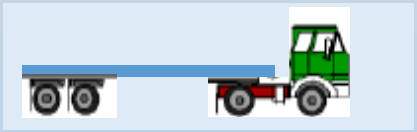


B. EVs in Highway Freight: Some Key Market Niches (Defined on Basis of Vehicle Size and Operational Geography)

1. Small Service Trucks and Vans (SEVs) (Urban, Local)

2a. Medium Duty Delivery Trucks and Vans (Urban, Regional)

2b. Medium-Heavy Duty Public Service (e.g. Utility, Garbage*) & Drayage Trucks (Urban, Short-Haul)



3. Heavy Duty Long Distance/Line-Haul Combination Trucks (Inter-City, Inter-Regional)

Recent and Expected Growth in the EV/HEV Truck Market

- Forecasting by Navigant Research (https://www.navigantresearch.com/) suggests that global sales of hybrid and electric trucks – including light duty trucks used by commercial fleets and all medium and heavy duty on-road trucks – will grow from under 10,000 in 2013 to more than 100,000 in 2020.

In addition to the > 26,000 Light Truck HEV, progress is being made in the U.S. within the Medium and Heavy Duty Truck Markets:

- 23 EV and HEV Medium/Heavy Truck models are listed by the US DOE's Alternative Fuels Data Center website (also in Table 6.7 in the 2015, Edition 34 of ORNL's Transportation Energy Data Book)

- There were an estimated 1,000 all-electric Medium Duty Trucks on US roads in early 2014, with sales projected to reach 3,500 to 6,000 units per year by 2020, (= approx. 1% to 3% of the overall U.S. medium duty truck market). (Lyden, S. *Green Fleet Magazine*, quoting Navigant Research, Jan/Feb 2014)

- In 2014 there were 113 electrified truck stop sites across the U.S. that could be used to reduce truck idling time. (Davis, S.C. et al, 2015. *2014 Vehicle Technologies Market Report*. ORNL-TM 2015/85)

1. Small Electric Vehicles (SEVs) for Intra-Urban Pickup & Delivery*

1a. Small Delivery Vans & Trucks:

gnewt cargo
love the last mile

battery - electric vans for retail distribution
London

DISTRIPOLIS®

Urban Consolidation Centers served by EVs.
France

MISSION ELECTRIC
NEW YORK CITY

PPP with NY Drugstore Chain Duane Reade (Walgreens): EV delivery trucks

LOGeco
Rome

Public/Private partnerships: encourages EV use in "last-mile" transportation

1b. E-Bikes, E-Trikes and E- Scooters: Includes cargo carriage using trailers (separate wheeled carrier attached behind bike), "longtails" (goods behind rider), and "long-johns" (goods ahead of rider)

La Petite Reine
Home deliveries by Cargocycles® and electric vans, **Paris**

Paris
the green link
urban mobility solutions
electric cargo cycles and vans

B-line sustainable urban delivery

electric-assisted freight bikes that can each deliver 700 lbs of goods in a 45-square-ft trailer.
Oregon http://b-linepdx.com/

Bentobox, Berlin
Lockers for parcels storage, and electrically assisted bikes for final delivery

1c. Truck + Multi-Trailer "Trains": Electric-driven 4 wheel truck trailer 'trains' with 2 or 3 small 4-wheel wagons attached behind (possibly using solar panels)

"last-mile" electric-powered "road train" deliveries,

Utrecht

cargohopper
stadsdistributie utrecht

*See https://www.electricbike.com/cargo/
http://frevue.eu/ http://www.bestfact.net/category/transport-modes/road-truck/
http://www.cleanenergyministerial.org/Portals/2/pdfs/EVI_2014_EV-City-Casebook.pdf

2. Positives Favoring Urban-based Medium and Medium-Heavy Duty EV Operations:

- Lower (urban network based) operating speed requirements and regenerative braking benefits of stop-go travel support more operational miles per battery charge.**

- Repetitive, return-to-base routing operations further reduce concerns over EV range suitability (once route viability established)

- Possible to build on/benefit from technological advances already going into transit buses and, most recently, into utility and drayage trucks (including dual-mode hybrids, fuel cell range extenders,…).***

Heavy Duty Electric Truck

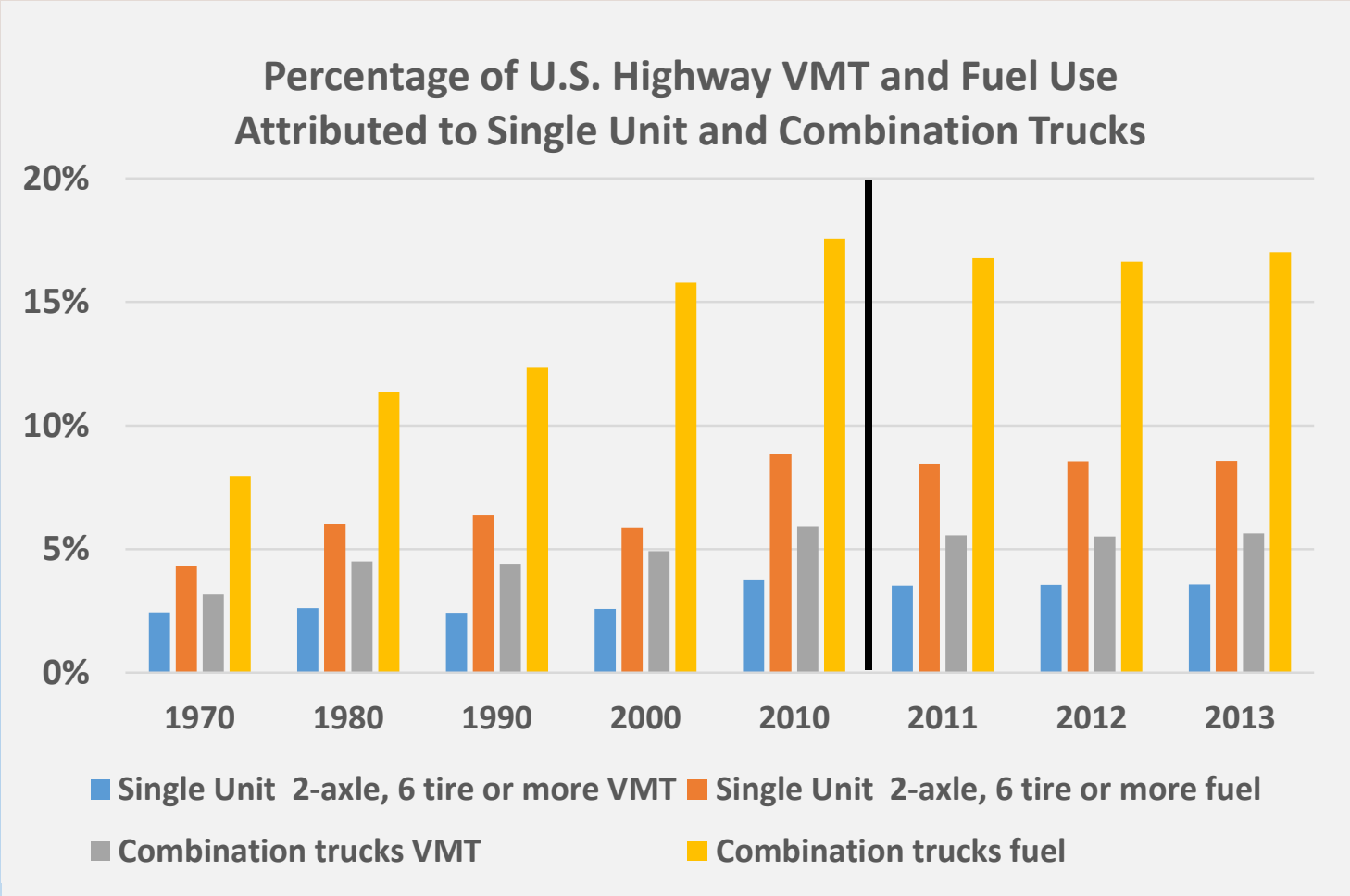
- Fleet vehicles may be bought on a life-cycle cost basis that should improve as operating and up front purchase costs fall**** and (existing) O&M cost savings become more effective.

- And significant savings in fossil fuel consumption are possible (next slide)

** A good deal of regenerative breaking can also reduce life-cycle brake replacement costs.
*** See, for example, E-traction's electric in-wheel powertrain technology for buses and city distribution trucks http://www.e-traction.eu/ and the all electric trucks tested as part of the *Hytruck Project* http://www.emoss.biz/news/eight-e-trucks-complete-hytruck-project/
**** See http://www.arb.ca.gov/msprog/tech/tech.htm for example

The U.S. has Seen Sustained Medium and Heavy Truck VMT Growth and Fossil Fuel Consumption since 1970*

In 2013 These Trucks accounted for 9.2% of annual VMT, but 25.6% of highway fossil fuel use



*Data Source: Bureau of Transportation Statistics Tables 1-35 (VMT) and 4-6 (Energy Consumption)
http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html

3. Possible Heavy Duty, Long-Haul Freight EV Applications

Stationary Power Supply Options:

- **BEV Hybrids Using Refueling Stations (and possibly battery switching stations??)**
- **PEV Hybrids Using Refueling & Re-Charging Stations**

THE U.S. SUPERTRUCK PROGRAM

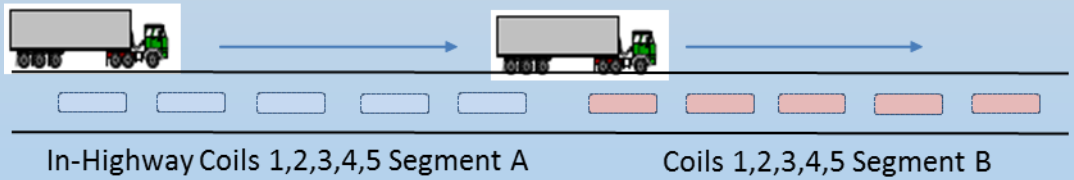
- **EV's Using In-Highway Wireless Recharging Pads***

Mobile Power Supply Options:

- **Conduction Charging of EVs via Catenary/Pantograph****

ENUBA 2 — Germany

- **Dynamic Wireless On-Road Charging of EVs**



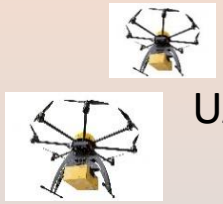
electrical coils in the road surface power vehicles via contactless electronic induction***

* See **Highways England (2015)** "*Feasibility study: powering electric vehicles on England's major roads*."
"The focus on early adopters should be on commercial operators, with a particular emphasis on road haulage companies using vehicles between 12t and 32.5t which regularly use particular stretches of the SRN *(Strategic Road Network)* ." p.12)

** See, for example, **Electrification of road freight transport** http://w3.siemens.com/topics/global/en/electromobility/pages/ehighway.aspx
http://www.siemens.com/press/en/feature/2015/mobility/2015-06-ehighway.php

EVs in Highway Freight: Connecting The (Supply Chain) Pieces

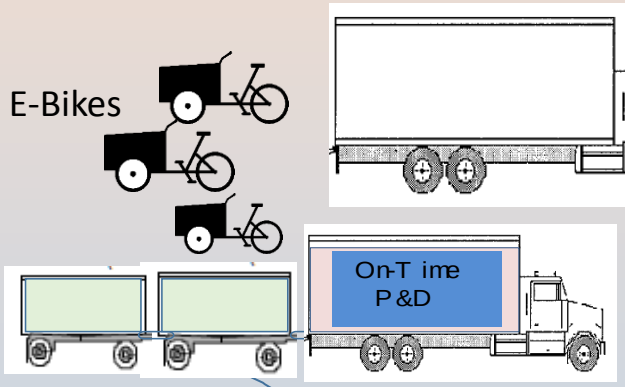
Intra-Urban
("First Mile- Last Mile" Freight)

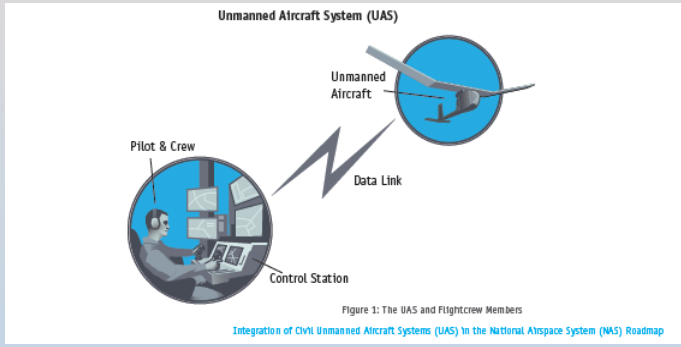


UAVs

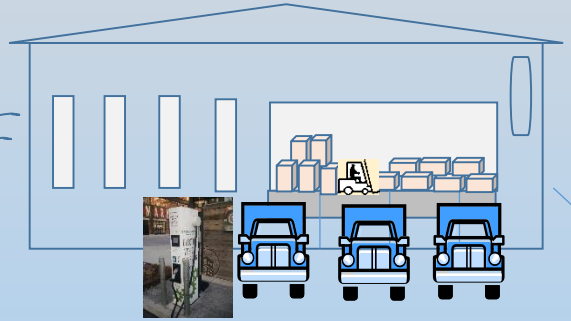
Aviation Innovation, Reform, and Reauthorization (AIRR) Act (H.R. 4441): a six-year reauthorization introduced into U.S. Congress (February, 2015) that includes UAS-related provisions that expedite safe deployment of commercial UAS by creating a risk-based permitting process

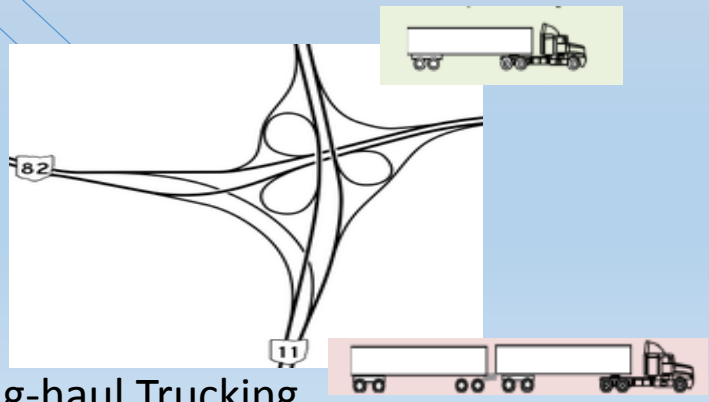
E-Bikes





Consolidation/Distribution Center





Long-haul Trucking

Possible E-Vehicle/E-Highway Futures

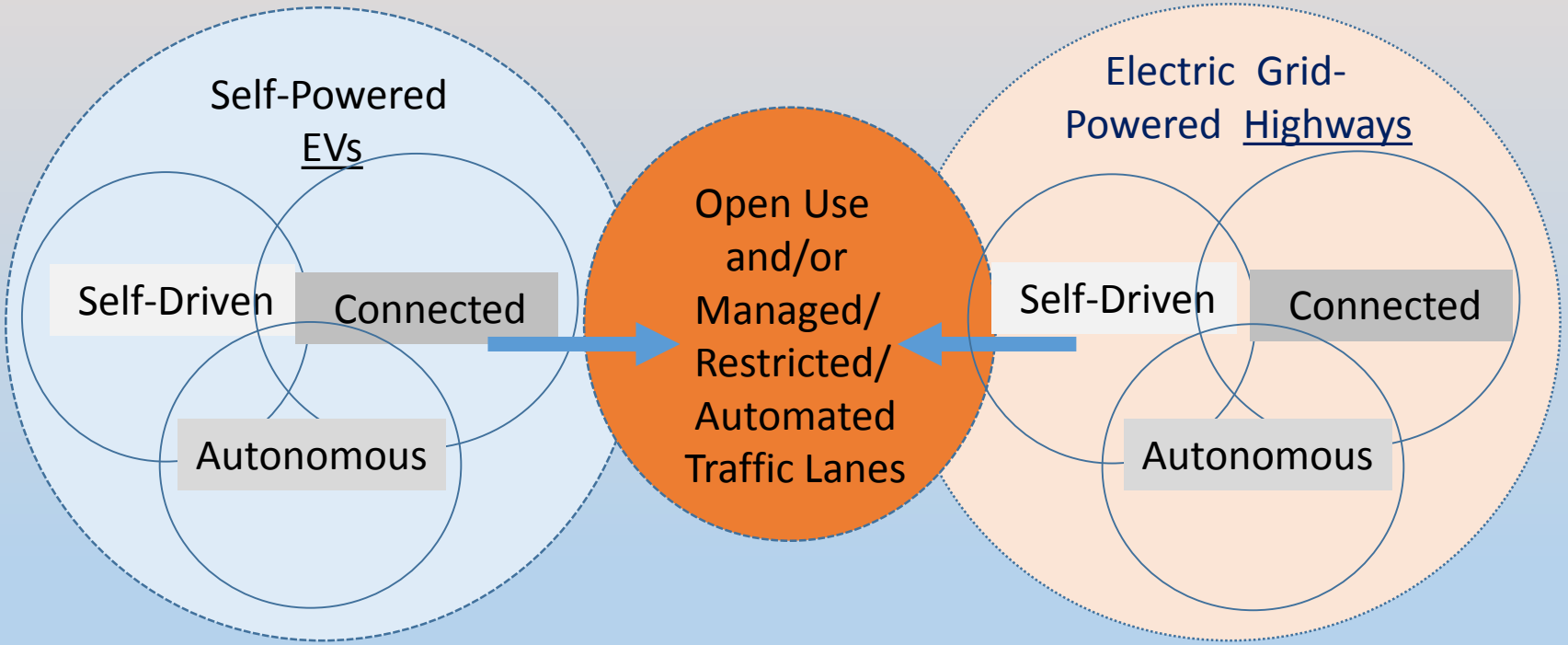
Battery/Fuel Cell
EVs and EV-Hybrids

Plug-In EVs and
EV Hybrids

Highway/Grid Controlled
EVs and EV Hybrids

Local/Urban Freight
(Trucking, E-Bikes)

Long-Haul Freight
(including Truck Platooning)



Privately Owned or Leased
Automobiles, SUVs & Small
Trucks/Vans, Taxis

Public Transit (Buses, Vans,
Jitneys, First/Last Mile Pods)

Autonomous EVs, Truck Convoys and E-Highways…….

"21st Century Clean Transportation Plan" with a proposed budget of $320B for 'clean transportation' over 10 years, funded by a new $10.25 per barrel fee on oil production, phased in over five years.

"Accelerate the integration of autonomous vehicles, low-carbon technologies, and intelligent transportation systems into our infrastructure."

"…investments in vehicle research and deployment would put commercial autonomous vehicles on the road both more quickly and more safely ***while ensuring electric cars*** and other alternatives to oil-based vehicles ***have the technology and the charging infrastructure they need***. "(*Italics added*).

OMB (2017) Budget of The U.S. Government. Fiscal Year 2017 Office of Management and Budget, Washington, D.C. Pages 18-19.

EXTRA SLIDES: FHWA Vehicle Size Classes

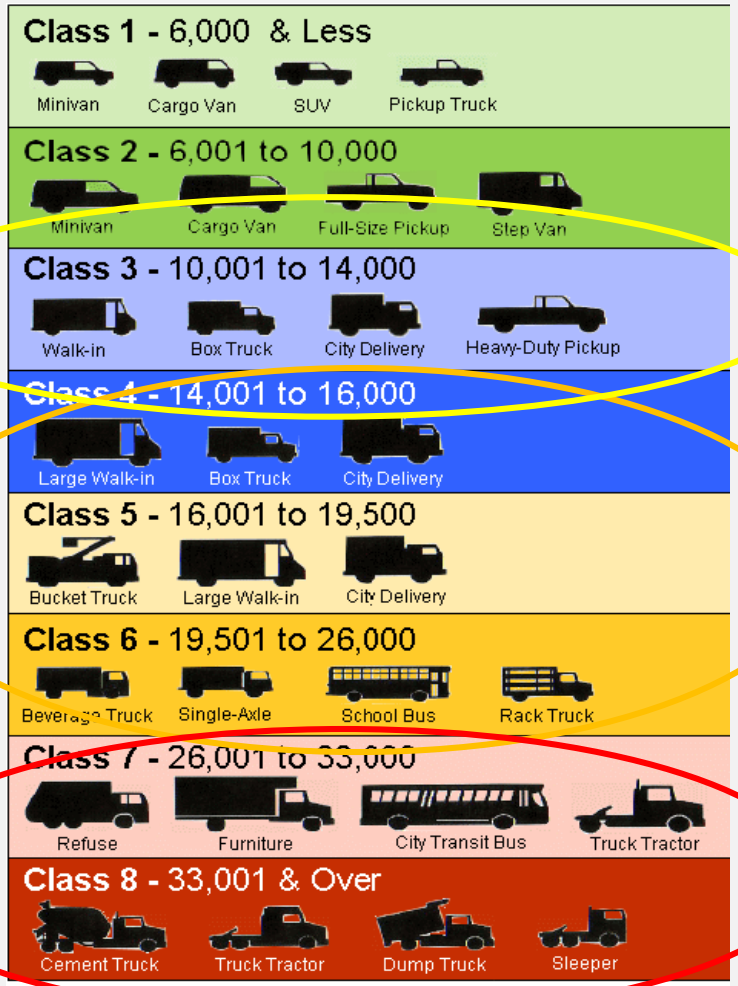
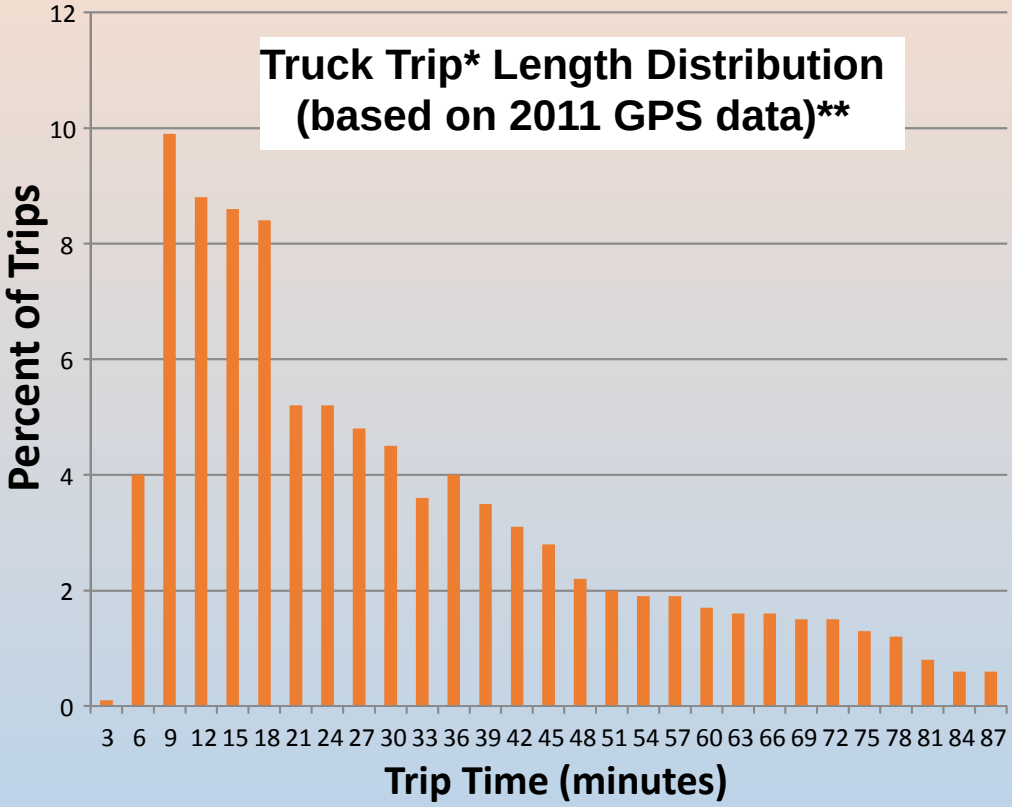


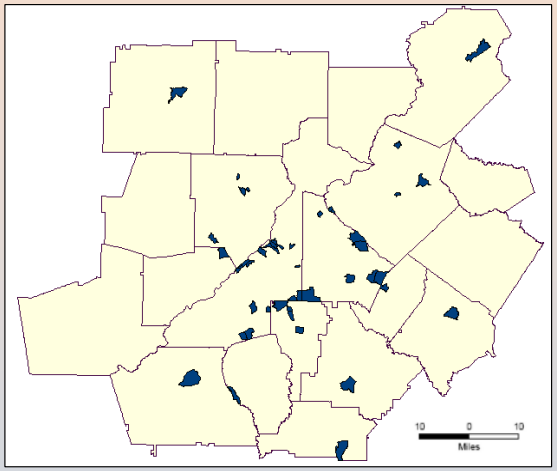
FIGURE 75. Examples of Trucks in Each Truck Class

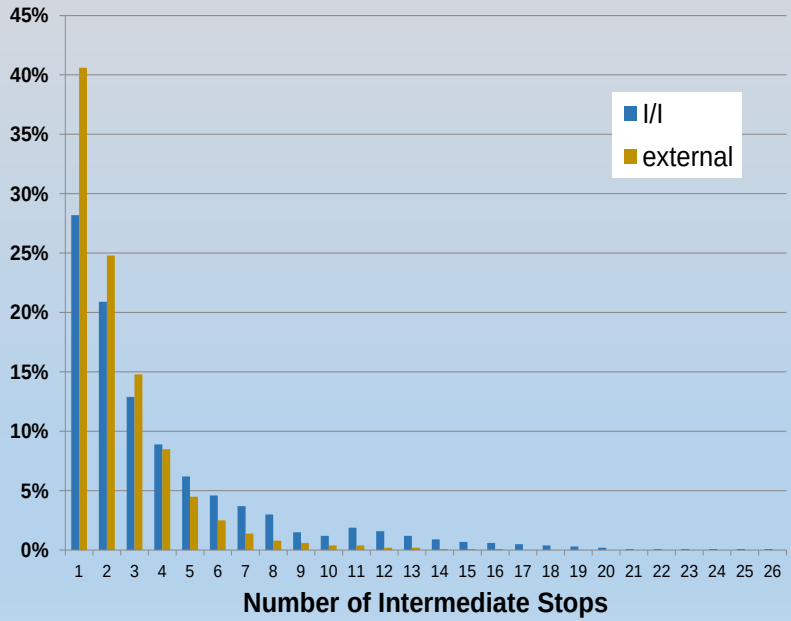
2014 Vehicle Technologies Market Report

Source:
Oak Ridge National Laboratory, Center for Transportation Analysis, Oak Ridge, TN.

Characteristics of Urban Truck Trip Tours: Atlanta, GA Example



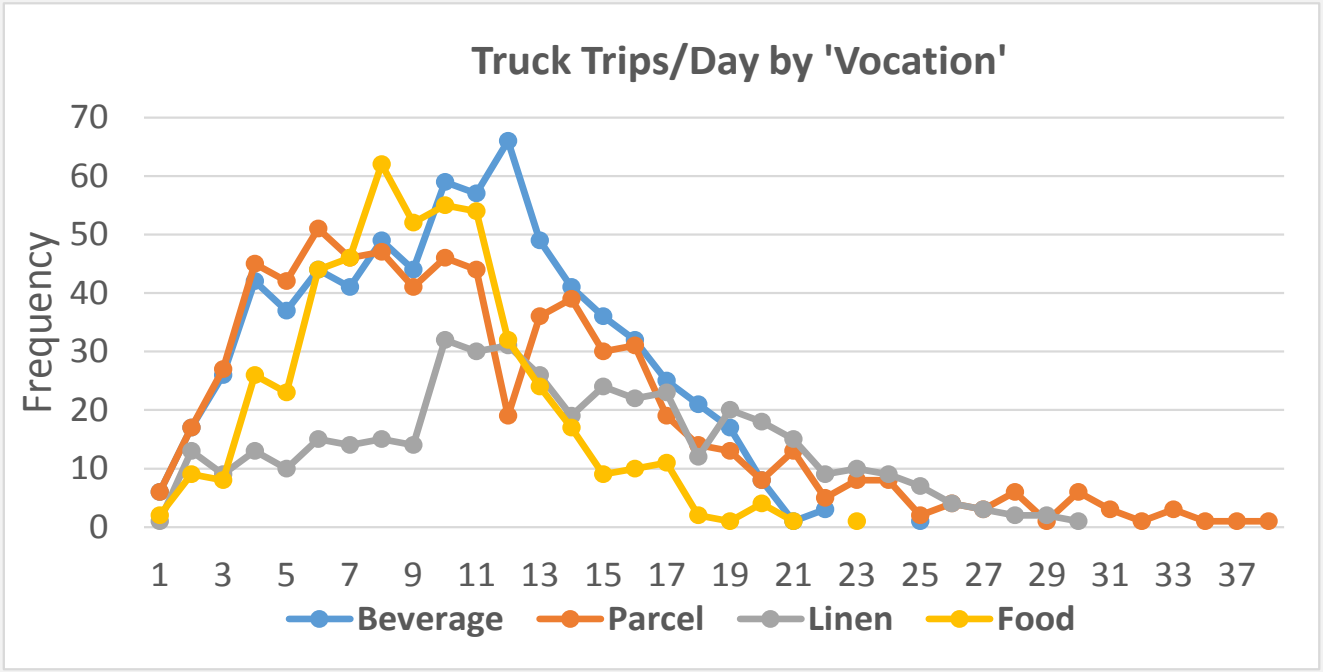




*A truck tour is a series of linked truck trips, or pickup/drop (P/D) stops. So a truck trip is either from a daily origin start location to the first pickup/drop (P/D) stop, a movement between any two subsequent P/D stops, or from the last P/D stop to a final daily destination. A truck may engage in more than one tour per day.

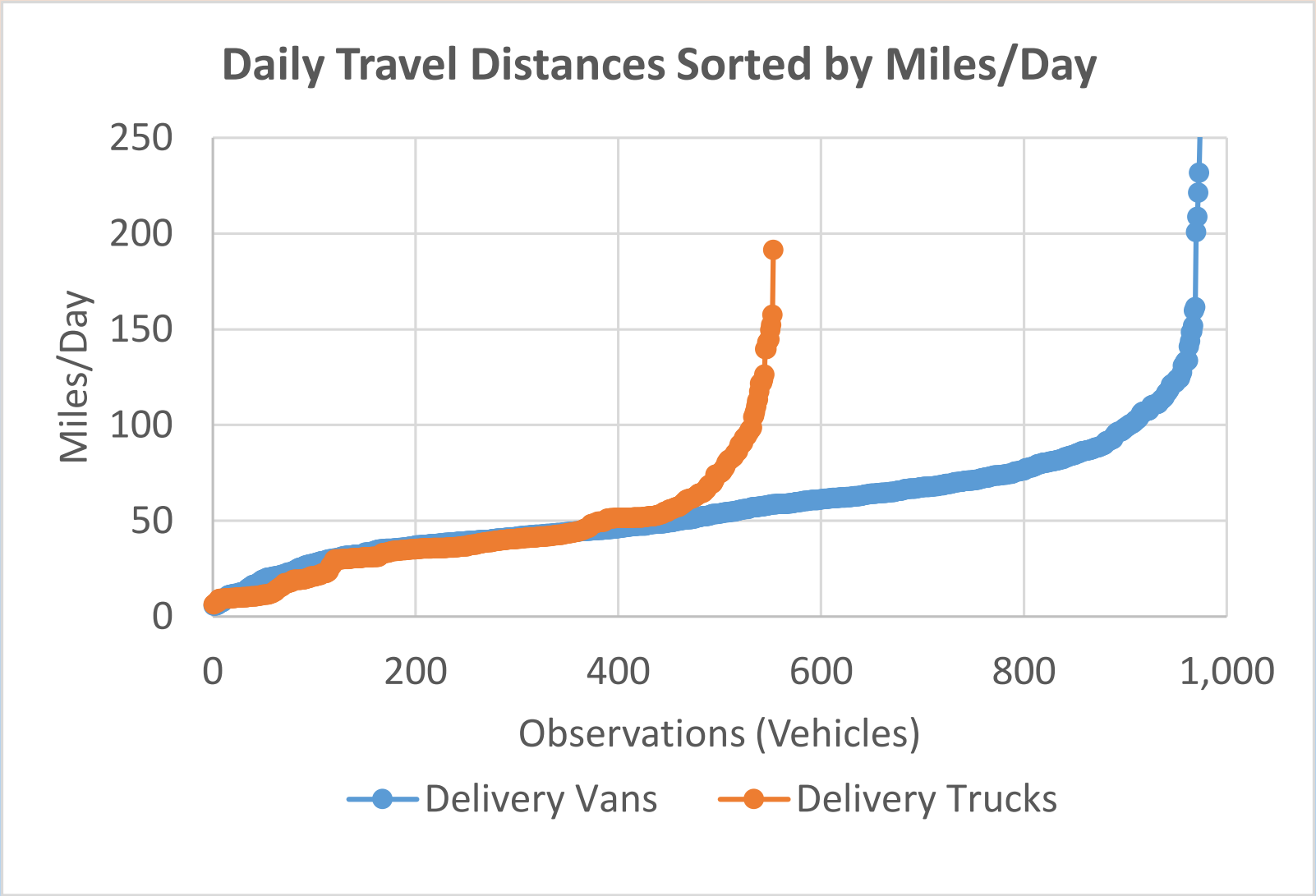
** Graphs based on Figures 30 and 32, in D. J-H Lee and C. L. Ross (2014) *Bringing Freight Components into Statewide and Regional Travel Demand Forecasting: PART1.* Center for Quality Growth and Regional Development, Georgia Institute of Technology, Atlanta, GA.

Number of Daily Truck Trips by Medium-Large Trucks based on a 2014 Data Sample: Variations by Vehicle Type and Type of Commodity Carried*



*Data Source: Truck DNA project, US DOE's National Renewable Energy Laboratory – 2014

See also: Duran et al (2014) *Characterization of In-Use Medium Duty Electric Vehicle Driving and Charging Behavior*, National Renewable Energy Laboratory, Golden, CO. for additional insights.



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